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EPA Office of Compliance Sector Notebook Project

Profile of the Pulp and Paper Industry

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This report is one in a series of volumes published by the U.S. Environmental Protection Agency (EPA) to provide information of general interest regarding environmental issues associated with specific industrial sectors. The documents were developed under contract by Abt Associates Inc. (Cambridge, MA), and Booz-Allen & Hamilton, Inc. (McLean, VA). This publication may be **purchased** from the Superintendent of Documents, U.S. Government Printing Office. A listing of available Sector Notebooks and document numbers is included at the end of this document.

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EPA/310-R-95-018.	Transportation Equip. Cleaning Ind.	Virginia Lathrop	564-7057

Pulp and Paper Industry Sector Notebook Contents

Exhibits Index

List of Acronyms

AF&PA -	American Forest & Paper Association
AFS -	AIRS Facility Subsystem (CAA database)
AIRS -	Aerometric Information Retrieval System (CAA database)
BIFs -	Boilers and Industrial Furnaces (RCRA)
BOD -	Biochemical Oxygen Demand
CAA -	Clean Air Act
CAAA -	Clean Air Act Amendments of 1990
CERCLA -	Comprehensive Environmental Response, Compensation and Liability Act
CERCLIS -	CERCLA Information System
CFCs -	Chlorofluorocarbons
CO -	Carbon Monoxide
COD -	Chemical Oxygen Demand
CSI -	Common Sense Initiative
CWA -	Clean Water Act
D&B -	Dun and Bradstreet Marketing Index
ELP -	Environmental Leadership Program
EPA -	United States Environmental Protection Agency
EPCRA-	Emergency Planning and Community Right-to-Know Act
FIFRA -	Federal Insecticide, Fungicide, and Rodenticide Act
FINDS -	Facility Indexing System
HAPs -	Hazardous Air Pollutants (CAA)
HSDB -	Hazardous Substances Data Bank
IDEA -	Integrated Data for Enforcement Analysis
LDR -	Land Disposal Restrictions (RCRA)
LEPCs -	Local Emergency Planning Committees
MACT -	Maximum Achievable Control Technology (CAA)
MCLGs -	Maximum Contaminant Level Goals
MCLs -	Maximum Contaminant Levels
MEK -	Methyl Ethyl Ketone
MSDSs -	Material Safety Data Sheets
NAAQS -	National Ambient Air Quality Standards (CAA)
NAFTA -	North American Free Trade Agreement
NCDB -	National Compliance Database (for TSCA, FIFRA, EPCRA)
NCP -	National Oil and Hazardous Substances Pollution Contingency Plan
NEIC -	National Enforcement Investigation Center
NESHAP -	National Emission Standards for Hazardous Air Pollutants
NO_2 -	Nitrogen Dioxide
NOV -	Notice of Violation

NO_X -	Nitrogen Oxides
NPDES -	National Pollution Discharge Elimination System (CWA)
NPL -	National Priorities List
NRC -	National Response Center
NSPS -	New Source Performance Standards (CAA)
OAR -	Office of Air and Radiation
OECA -	Office of Enforcement and Compliance Assurance
OPA -	Oil Pollution Act
OPPTS -	Office of Prevention, Pesticides, and Toxic Substances
OSHA -	Occupational Safety and Health Administration
OSW -	Office of Solid Waste
OSWER -	Office of Solid Waste and Emergency Response
OW -	Office of Water
P2 -	Pollution Prevention
PCS -	Permit Compliance System (CWA Database)
POTW -	Publicly Owned Treatments Works
RCRA -	Resource Conservation and Recovery Act
RCRIS -	RCRA Information System
SARA -	Superfund Amendments and Reauthorization Act
SDWA -	Safe Drinking Water Act
SEPs -	Supplementary Environmental Projects
SERCs -	State Emergency Response Commissions
SIC -	Standard Industrial Classification
SO_2 -	Sulfur Dioxide
SO_X -	Sulfur Oxides
TOC -	Total Organic Carbon
TRI -	Toxic Release Inventory
TRIS -	Toxic Release Inventory System
TCRIS -	Toxic Chemical Release Inventory System
TSCA -	Toxic Substances Control Act
TSS -	Total Suspended Solids
UIC -	Underground Injection Control (SDWA)
UST -	Underground Storage Tanks (RCRA)
VOCs -	Volatile Organic Compounds

I. INTRODUCTION TO THE SECTOR NOTEBOOK PROJECT

I.A. Summary of the Sector Notebook Project

Environmental policies based upon comprehensive analysis of air, water and land pollution (such as economic sector, and community-based approaches) are becoming an important supplement to traditional single-media approaches to environmental protection. Environmental regulatory agencies are beginning to embrace comprehensive, multi-statute solutions to facility permitting, compliance assurance, education/outreach, research, and regulatory development issues. The central concepts driving the new policy direction are that pollutant releases to each environmental medium (air, water, and land) affect each other, and that environmental strategies must actively identify and address these inter-relationships by designing policies for the "whole" facility. One way to achieve a whole facility focus is to design environmental policies for similar industrial facilities. By doing so, environmental concerns that are common to the manufacturing of similar products can be addressed in a comprehensive manner. The desire to move forward with this "sector-based" approach within the EPA Office of Compliance led to the creation of this document.

The Sector Notebook Project was initiated by the Office of Compliance to provide its staff and managers with summary information for eighteen specific industrial sectors. As other EPA offices, states, the regulated community, and the public became interested in this project, the Office of Compliance expanded the scope of the original project. The ability to design comprehensive, common sense environmental protection measures for specific industries is dependent on knowledge of several inter-related topics. For the purposes of this project, the key elements chosen for inclusion are: general industry information (economic and geographic); a description of industrial processes; pollution outputs; pollution prevention opportunities; Federal statutory and regulatory framework; compliance history; and a description of partnerships that have been formed between regulatory agencies, the regulated community and the public.

For any given industry, each topic described above could alone be the subject of a lengthy volume. However, in order to produce a manageable document, this project focuses on providing summary information for each topic. This format provides the reader with a synopsis of each issue, and references where more in-depth information is desired. Text within each profile was researched from a variety of sources, and was usually condensed from more detailed sources pertaining to specific topics. This approach allows for a wide coverage of activities that can be further explored based upon the citations and references listed at the end of this profile. As a check on the information included, each notebook went through an external document review process. The Office of Compliance appreciates the efforts of all those that participated in this process and enabled us to develop more complete, accurate and up-to-date summaries. Many of those who reviewed this notebook are listed as contacts in Section IX and may be sources of additional information. The individuals and groups on this list do not necessarily concur with all statements within this notebook.

I.B. Additional Information

Providing Comments

The Office of Compliance plans to periodically review and update notebooks and will make these updates available both in hard copy and electronically. If you have any comments on the existing notebook, or if you would like to provide additional information, please send a hard copy and computer disk to the EPA Office of Compliance, Sector Notebook Project, 401 M St., SW (2223-A), Washington, DC 20460. Comments can also be uploaded to the Enviroene Bulletin Board or the Enviroene World Wide Web for general access to all users of the system. Follow instructions in Appendix A for accessing these data systems. Once you have logged in, procedures for uploading text are available from the on-line Enviroene Help System.

Adapting Notebooks to Particular Needs

The scope of the existing notebooks reflect an approximation of the relative national occurrence of facility types that occur within each sector. In many instances, industries within specific geographic regions or states may have unique characteristics that are not fully captured in these profiles. For this reason, the Office of Compliance encourages state and local environmental agencies and other groups to supplement or re-package the information included in this notebook to include more specific industrial and regulatory information that may be available. Additionally, interested states may want to supplement the "Summary of Applicable Federal Statutes and Regulations" section with state and local requirements. Compliance or technical assistance providers may also want to develop the "Pollution Prevention" section in more detail. Please contact the appropriate specialist listed on the opening page of this notebook if your office is interested in assisting us in the further development of the information or policies addressed within this volume.

If you are interested in assisting in the development of new notebooks for sectors not covered in the original eighteen, please contact the Office of Compliance at 202-564-2395.

II. INTRODUCTION TO THE PULP AND PAPER INDUSTRY

This section provides background information on the size, geographic distribution, employment, production, sales, and economic condition of the pulp and paper industry. The type of facilities described within the document are also described in terms of their Standard Industrial Classification (SIC) codes. Additionally, this section contains a list of the largest companies in terms of sales.

II.A. Introduction, Background, and Scope of the Notebook

This notebook focuses primarily on the greatest areas of environmental concerns within the pulp and paper industry: those from pulpmaking processes. Due to this focus, some components of the pulp and paper industry, as defined by SIC code 26, are not addressed in this notebook. Converting facilities are not discussed, and the papermaking stage of the pulp and paper process is de-emphasized. Data has been drawn from industry and census sources in the preparation of this document.

According to a 1990 USEPA survey of pulp and paper mills and industry statistics, there are approximately 555 facilities manufacturing pulp and paper in the U.S. Of these facilities, about half are integrated facilities manufacturing both pulp and paper products, half manufacture only paper products and approximately 50 mills produce only pulp.[a,1] In 1991, pulp and paper mills employed approximately 198,000 people and produced $54 billion in shipments. Shipments from facilities producing converted products were approximately $75 billion.[2] In comparison, the industry total value of shipments (pulp and paper mills and converting facilities) accounted for about 4 percent of the value of shipments for the entire U.S. manufacturing sector and was similar to that of the petroleum refining sector. Pulp and paper mills tend to be large and capital intensive. Almost three quarters of U.S. mills employ over 100 people. Converting facilities tend to be smaller, more numerous and more labor intensive. The geographic distribution of mills producing pulp and paper and those producing only paper products varies. Pulp and paper mills tend to be located where pulp trees are harvested: Southeast, Northwest, Northeast, and North Central regions. Paper and paper board mills are more widely distributed in the proximity of pulping operations and near converting

[a] Variation in facility counts occur across data sources due to many factors, including reporting and definitional differences. This notebook does not attempt to reconcile these differences, but rather reports the data as they are maintained by each source.

sector markets.[3] Deinked pulp mills are often located near recovered paper sources in urban areas.

One important characteristic of the pulp and paper industry is the interconnection of operations between pulp mills, of which there are fewer than 60 in the U.S., and downstream processing of pulp into paper, paperboard and building paper. Another important characteristic of the pulp and paper industry are the varied processes, chemical inputs, and outputs that are used in pulp manufacture. Chemical recovery systems reuse many process chemicals for some of these pulpmaking systems. On the whole, however, pulp mill processes are chemical intensive and have been the focus of past and ongoing rulemaking. In many analyses of the sector, they should be considered separately. The Bureau of the Census' two-digit SIC 26 also includes a number of SIC codes related to converting, i.e., manufacturing finished paper and paperboard products from paper and paperboard stock, not milling. These converting operations fall under the three-digit SIC 265 - Paperboard Containers and Boxes and SIC 267 - Miscellaneous Converted Paper Products. Some companies are involved in both the manufacture of primary products and converting, especially in the production of sanitary tissue products, corrugated shipping containers, folding cartons, flexible packaging, and envelopes. (These types of integrated facilities are among the largest convertors.) The following list includes pulp and paper mills (italicized) as well as converted paper products included within SIC 26.

SIC 2611 - Pulp mills
SIC 2621 - Paper mills
SIC 2631 - Paperboard mills
SIC 2652 - Setup paperboard boxes
SIC 2653 - Corrugated and solid fiber boxes
SIC 2655 - Fiber cans, drums, and similar products
SIC 2656 - Sanitary food containers
SIC 2657 - Folding paperboard boxes
SIC 2661 - Building paper and building board mills
SIC 2671 - Paper coated and laminated, packaging
SIC 2672 - Paper coated and laminated, nec
SIC 2673 - Bags: plastics, laminated, and coated
SIC 2674 - Bags: uncoated paper and multiwall
SIC 2675 - Die-cut paper and board
SIC 2676 - Sanitary paper napkins
SIC 2677 - Envelopes
SIC 2678 - Stationery products
SIC 2679 - Converted paper products, nec

II.B. Characterization of the Pulp and Paper Industry

The pulp and paper industry produces commodity grades of wood pulp, primary paper products, and paper board products such as: printing and writing papers, sanitary tissue, industrial-type papers, container board and boxboard. Pulp facilities are comprised of mills that only produce pulp which is sold on the open market or is shipped via pipe, conveyor, truck, train, or ship to another facility where it is utilized for the production of a final product. Pulp and paper facilities are comprised of mills that produce both pulp and primary paper products, and mills that produce only paper products from pulp produced elsewhere. SIC code 26 also includes facilities that "convert" primary paper and paper board products to finished paper products such as: packaging, envelopes and shipping containers. In the following analysis of the pulp and paper industry, converting facilities are treated separately from pulp and paper mills due to major differences in the industrial processes, environmental releases, facility size and number, and relevant environmental regulations.

The processes used to manufacture pulp (which is later converted into paper) are the major sources of environmental concerns for this industry. Pulpmaking processes are the sources of air and water pollutant outputs. Although a variety of processes are used nationally, the vast majority of pulp tonnage produced in the U.S. is manufactured by the kraft chemical pulping process, which may release nuisance odors and particulates to the air. Bleaching processes, primarily used to whiten and brighten pulps for paper manufacture, may produce wastewaters containing chlorinated compounds such as dioxins. Overall, the pulp and paper making process is water-intensive: the pulp and paper industry is the largest industrial process water user in the U.S.[4] In 1988, a typical pulp and paper mill used 16,000 to 17,000 gallons of water per ton of pulp produced. This roughly translates into an industry total discharge amount of 16 million m^3/day of water.[5] Pulp and paper mills usually operate wastewater treatment plants to remove biological oxygen demand (BOD), total suspended solids (TSS), and other pollutants before discharging wastewaters to a receiving waterway. Mills with indirect discharge may operate primary treatment systems designed for TSS reduction prior to discharge to a POTW.

Generally speaking, the pulp and paper industry divides itself along pulping process lines: chemical pulping (e.g., kraft chemical pulping), mechanical pulping, and semi-chemical pulping. On a tonnage basis, chemical pulping methods produced approximately 85 percent of the pulp manufactured domestically in 1991, mechanical pulp 10 percent and semi-chemical five percent.[6]

II.B.1. Industry Size and Geographic Distribution

The approximately 555 manufacturing pulp and paper mills in the U.S. can be divided into three major categories. In the pulp and paper industry, some mills produce pulp only (market pulp facilities), some only manufacture paper from pulp (non-integrated facilities), and some produce the pulp they use for paper manufacture on-site (integrated facilities). Of the estimated 555 pulp and paper facilities in the U.S., 55 are market pulp facilities, 300 are non-integrated facilities, and 200 are integrated facilities.[7]

The Bureau of the Census tracks the pulp and paper industry at the two-digit Standard Industrial Classification (SIC) code level using SIC 26 which encompasses paper and allied products. Environmental regulations frequently distinguish primary product mills (2611, 2621, 2631, 2661) from converting operations. The pulp and paper industry is a capital intensive sector with large facilities. With increases in automation and industry restructuring, the ratio of employees to value of shipments has declined since 1972 as have the number of facilities in operation (23 percent reduction since 1972). Almost three-quarters of U.S. mills in the *1992 Census of Manufactures* employ 100 people or more. Converting facilities, those that use the primary pulp, paper and paperboard products, tend to be smaller, more numerous and more labor-intensive.

Exhibit 1: Large Facilities Dominate Industry (SICs 2611, 2621, 2631)

Employees per Facility	Percentage of Facilities (total=529)
1-19	2%
20-99	28%
100-499	44%
500-999	17%
1,000-2,499	9%

Source: *U.S. Census of Manufactures, 1992*

The geographic distribution of pulp and paper mills varies according to the type of mill. As there are tremendous variations in the scale of individual facilities, tallies of the number of facilities may not represent the level of economic activity (nor possible environmental consequences). Pulp mills are located primarily in regions of the country where pulp trees are harvested from natural stands or tree farms: the Southeast, Northwest, Northeast and Northern Central regions. Paper mills, however, are more widely distributed, located in proximity to pulping operations and/or near converting sector markets. The distribution of paperboard mills follows the location of manufacturing in general since such operations are the primary market for paperboards products.

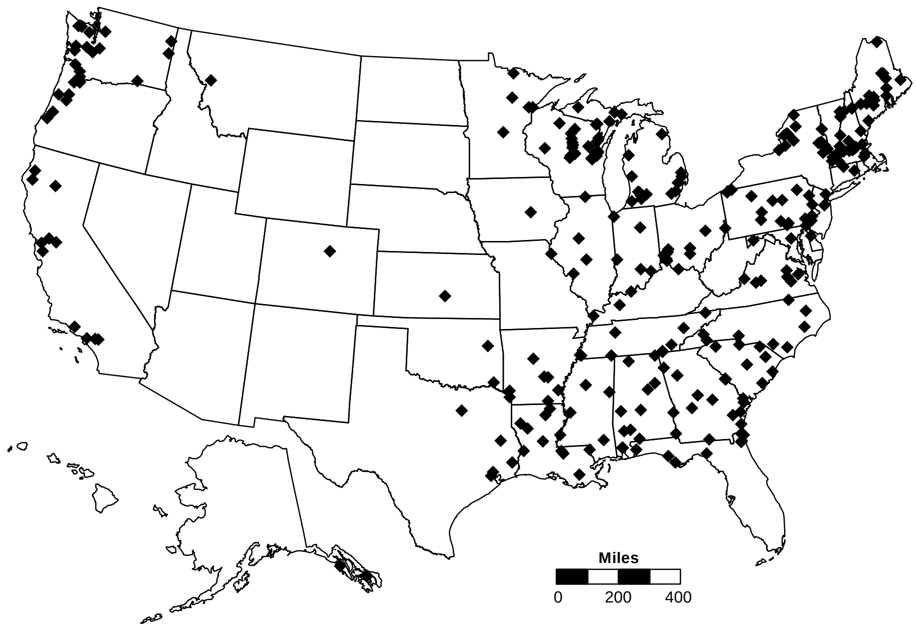
Exhibit 2: Geographic Distribution of Mills Differs According to Type of Mill

Mill Type	Top States, descending (% of U.S. Total, by type)	Secondary States (% of U.S. Total, by type)
Pulp Mills	WA, GA, WI, AL, CA, NC, TN, AK, FL, ME, MS (94%)	MI, KY (6%)
Paper Mills	WI, NY, MA, MI (42%)	PA, OH, ME, WA, NH, CA, MN, LA (39%)
Paperboard Mills	CA, OH, PA, MI, GA, NY (45%)	NJ, VA, AL, IN, IL, TN, CT, FL, LA, OR, TX (40%)

Note: States with three to five percent of the U.S. total of that mill type are listed as Secondary States. Those with six percent or more of the U.S. total are listed as Top States. Those with two percent or less are not listed.

Source: U.S. EPA, *Development Documents for Proposed Effluent Limitations Guidelines and Standards for the Pulp, Paper and Paperboard Point Source Category*. October 1993.

Exhibit 3: Pulp, Paper, and Paperboard Mills



(Source: U.S. EPA, Toxics Release Inventory Database, 1993.)

Ward's Business Directory of U.S. Private and Public Companies, produced by Gale Research Inc., compiles financial data on U.S. companies including those operating within the pulp and paper industry. Ward's ranks U.S. companies, whether they are a parent company, subsidiary or division, by sales volume within the four-digit SIC codes that they have been assigned as their primary activity. Readers should note that: 1) Companies are assigned a four-digit SIC that most closely resembles their principal industry; and 2) Sales figures include total company sales, including sales derived from subsidiaries and operations not related to pulp and paper production. Additional sources of company-specific financial information include Standard & Poor's Stock Report Services, Dun & Bradstreet's Million Dollar Directory, Moody's Manuals, Lockwood-Post's Directory, and annual reports.

Exhibit 4: Top U.S. Companies with Pulp and Paper Manufacturing Operations

Rank[a]	**Company**[b]	**1993 Sales** (millions of dollars)
1	International Paper Co.	12,703
2	Weyerhaeuser Co.	8,702
3	Kimberly-Clark Corp.	6,777
4	Georgia-Pacific Corp. Pulp and Paper Group	6,702
5	Stone Container Corp.	5,384
6	Champion International Corp.	4,786
7	Mead Corp.	4,579
8	Boise Cascade Corp.	3,951
9	Union Camp Corp.	2,967
10	Jefferson Smurfit Corp.	2,940

Note: [a] When *Ward's Business Directory* listed both a parent and subsidiary in the top ten, only the parent company is presented above to avoid double counting sales volumes. Not all sales can be attributed to the companies' pulp and paper operations.
[b] Companies shown listed SIC 2611, 2621, or 2631 as primary activity.

Source: *Ward's Business Directory of U.S. Private and Public Companies*, 1993.

II.B.2. Product Characterization

The pulp and paper industry produces primary products -- commodity grades of wood pulp, printing and writing papers, sanitary tissue, industrial-type papers, containerboard and boxboard -- using cellulose fiber from timber or purchased or recycled fibers. Paper and Allied Products are categorized by the Bureau of the Census as Standard Industrial Classification (SIC) code 26. The industry's output is "converted" to finished products such as packaging, envelopes and shipping containers by independent manufacturing facilities or at facilities located adjacent to a mill. Converting operations are included in SIC 26 but are not included in the following profiles of the pulp and paper industry unless noted.

The products of the pulp and paper industry can also be categorized by the pulping process used in paper and paperboard production. The pulping process affects the strength, appearance, and intended use characteristics of the resultant paper product. Pulping processes are the major source of environmental impacts in the pulp and paper industry; each pulping process has its own set of process inputs, outputs, and resultant environmental concerns. Papermaking activities have not been associated with significant environmental problems and are not addressed by EPA's ongoing regulatory and nonregulatory initiatives. Industry representatives and EPA, in the Proposed Effluent Limitations Guidelines and Standards for the Pulp, Paper and Paperboard Point Source Category, have used pulpmaking techniques to categorize the majority of the industry (Exhibit 5). Since many mills operate a variety of pulping processes, the percentages in Exhibit 5 are not additive. In addition, the data indicates process prevalence at mills but does not represent the proportion of pulp manufactured by each processes. For example, many mills practice some form of deink secondary fiber pulping as shown in Exhibit 5, but the great majority of U.S. pulp is produced by the kraft chemical pulping process. (The pulp and papermaking processes contained in Exhibit 5 are explained in Section III: Industrial Process Description.)

Exhibit 5: Number of Mills in U.S. by Pulping Process		
Pulp Process	***% of Mills****	***Description/Principal Products***
Dissolving Kraft	1	Highly bleached and purified kraft process wood pulp suitable for conversion into products such as rayon, viscose, acetate, and cellophane.
Bleached Papergrade Kraft and Soda	24	Bleached or unbleached kraft process wood pulp usually converted into paperboard, coarse papers, tissue papers, and fine papers such as business, writing and printing.
Unbleached Kraft	10	
Dissolving Sulfite	1	Highly bleached and purified sulfite process wood pulp suitable for conversion into products such as rayon, viscose, acetate, and cellophane.
Papergrade Sulfite	3	Sulfite process wood pulp with or without bleaching used for products such as tissue papers, fine papers, and newsprint.
Semi-chemical	6	Pulp is produced by chemical, pressure, and mechanical (sometimes) forces with or without bleaching used for corrugating medium (for cardboard), paper, and paperboard.

Exhibit 5: Number of Mills in U.S. by Pulping Process

Pulp Process	*% of Mills**	*Description/Principal Products*
Mechanical pulp	<12	Pulp manufacture by stone groundwood, mechanical refiner, thermo-mechanical, chemi-mechanical, or chemi-thermo-mechanical means for newsprint, coarse papers, tissue, molded fiber products, and fine papers.
Non-wood Chemical pulp	2	Production of pulp from textiles (e.g.,rags), cotton linters, flax, hemp, tobacco, and abaca to make cigarette wrap papers and other specialty paper products.
Secondary Fiber Deink	8	Pulps from wastepapers or paperboard using a chemical or solvent process to remove contaminants such as inks, coatings and pigments used to produce fine, tissue, and newsprint papers.
Secondary Fiber Non-deink	61	Pulp production from wastepapers or paperboard without deinking processes to produce tissue, paperboard, molded products and construction papers.
Fine and Lightweight Papers from Purchased Pulp	44	Paper production from purchased market pulp or secondary fibers to make clay coated printing, uncoated free sheet, cotton fiber writing, and lightweight electrical papers.

Exhibit 5: Number of Mills in U.S. by Pulping Process

Pulp Process	*% of Mills**	*Description/Principal Products*
Tissue, Filter, Non-Woven, and Paperboard from Purchased Pulp		Paper production from purchased market pulp to make paperboard, tissue papers, filter papers, non-woven items, and any products other than fine and lightweight papers.

* Percents are not additive because many mills operate multiple fiber lines and processes.

Source: USEPA. *Development Document for Proposed Effluent Limitations Guidelines and Standards for the Pulp, Paper, and Paperboard Point Source Category*. October 1993.

II.B.3. Economic Trends

The pulp and paper industry is a capital intensive sector with large facilities in terms of number of employees and chemical use. With increases in automation and industry restructuring, the ratio of employees to value of shipments has declined since 1972 as have the number of facilities in operation (23 percent reduction since 1972). Almost three-quarters of U.S. mills in the *1992 Census of Manufactures* employ 100 people or more. Converting facilities, those that use the primary pulp, paper and paperboard products tend to be smaller, more numerous and more labor-intensive.

The Bureau of the Census estimates that in 1992, 198,000 people were employed in pulp and paper mills with a payroll of $8.25 billion. The value of shipments generated by the pulp and paper sector totaled approximately $54 billion. Industry growth is expected to average two percent per year through 1998 due in large part to expected increases in exports.

The U.S. pulp and paper industry is recognized as a high-quality, high-volume, low-cost producer that benefits from a large consumer base, a modern technical infrastructure, adequate raw materials and a highly skilled labor force. Profitability within the industry is a function both of raw material prices and labor conditions as well as worldwide inventories and demand. Reduced profitability since 1991 due to decreased demand, high inventories, and higher prices of wood products led to rebuilding and modifications of existing equipment rather than installation of new machines. In 1993, domestic mills operated at between 92 and 95 percent of capacity.[8]

Within the manufacture of primary products, paper mills (SIC 2621) account for 60 percent of the total value of shipments. The remaining shipments are attributable to paperboard mills which account for 30 percent of total value of shipments and pulp mills at 10 percent. The majority of converting operations are operate independently of a primary product mill (e.g. a paper stock mill). However, those mills that are integrated with primary product mills account for the majority of the value of shipments.

The 1992 Census of Manufactures reports a payroll of $8.25 billion for 198,000 employees in the primary products sectors, three-quarters of whom are production workers. Labor relations are critical to the success of U.S. pulp and paper operations. Employment is down slightly, caused by mergers, consolidations and phasing out of older, less-efficient operations, a trend which is expected to continue. Nonetheless, labor contracts are being signed for longer periods and strikes are less frequent (one in 1993 versus 19 in 1983).

Industry growth is driven by the performance of other manufacturing sectors that use paper products in packaging and by demand for printing and writing papers. Competitive pressures come from plastic packaging in the domestic market. As foreign paper companies in developing countries improve their product quality they are likely to become more competitive in the U.S. and international markets. Current principal world market competition comes from Canada and Scandinavia.

Exports of pulp and paper products are increasingly important to the economic health of the industry. In 1992, exports amounted to $10.1 billion (seven percent of the total value of shipments of paper and allied products). The major export markets for U.S. printed material are Canada, Mexico, and Japan. Efforts by the U.S. paper industry to meet new European Community guidelines and product standards should strengthen its competitive position in European markets. During the same period, the U.S. imported $10.4 billion worth of pulp and paper products, principally from Canada. Even with the recent weakness in Canada's economy, exports (particularly of converted paper and paperboard packaging) are likely to grow due to the U.S.-Canada Free Trade Agreement. A large number of U.S. paper and paperboard companies that have not yet entered overseas markets will likely do so if tariff and nontariff barriers are removed or reduced. Exports of recovered paper, which are not included in the figures above, totaled $560 million in 1993; imports totaled $26 million.

Domestic demand for packaging and industrial-type paper grades and strengthening export markets drive estimates for real growth of three percent in shipments of paper and allied products in 1994. The successful conclusion of the North American Free Trade Agreement (NAFTA) and the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) is also increasing exports for the industry particularly to the European Community and emerging economies in Pacific Rim countries. Industry growth is expected to average two percent per year through 1998 due in large part to expected increases in exports.

III. INDUSTRIAL PROCESS DESCRIPTION

This section describes the major industrial processes within the pulp and paper industry, including the materials and equipment used, and the processes employed. The section is designed for those interested in gaining a general understanding of the industry, and for those interested in the inter-relationship between the industrial process and the topics described in subsequent sections of this profile -- pollutant outputs, pollution prevention opportunities, and Federal regulations. This section does not attempt to replicate published engineering information that is available for this industry. Refer to Section IX for a list of reference documents that are available.

This section specifically contains a description of commonly used production processes, associated raw materials, the byproducts produced or released, and the materials either recycled or transferred off-site. This discussion, coupled with schematic drawings of the identified processes, provide a concise description of where wastes may be produced in the process. This section also describes the potential fate (via air, water, and soil pathways) of these waste products.

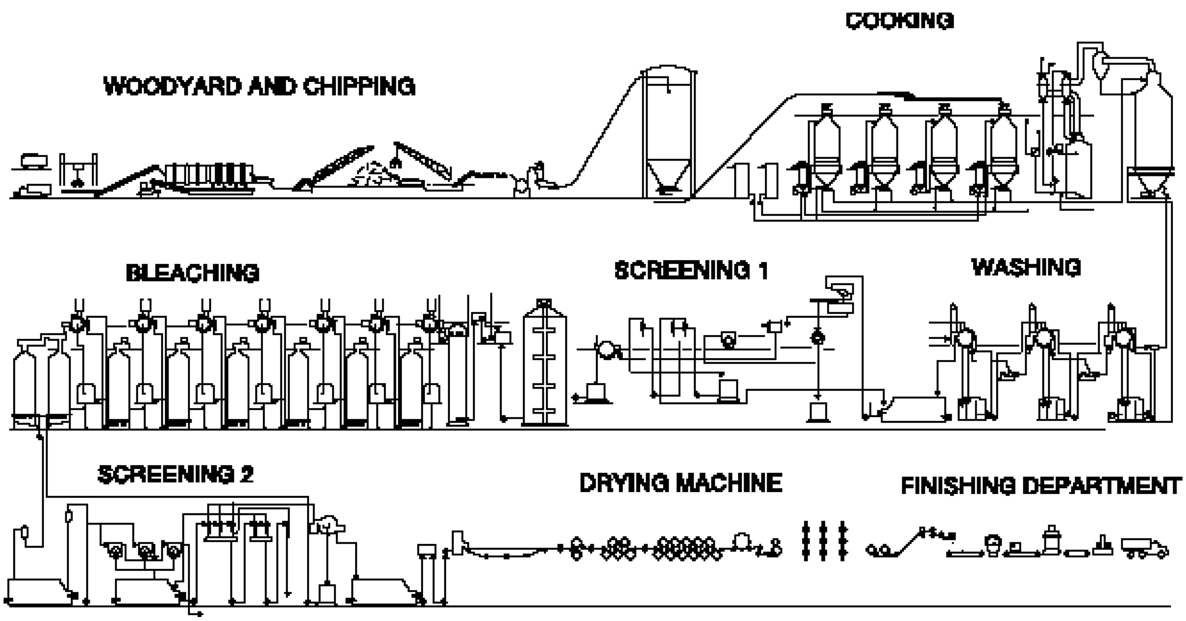
III.A. Industrial Processes in the Pulp and Paper Industry

Simply put, paper is manufactured by applying a watery suspension of celluose fibers to a screen which allows the water to drain and leaves the fibrous particles behind in a sheet. Most modern paper products contain non-fibrous additives, but otherwise fall within this general definition. Only a few paper products for specialized uses are created without the use of water, via dry forming techniques. The watery fibrous substrate formed into paper sheets is called pulp. The production of pulp is the major source of environmental impacts in the pulp and paper industry.

Processes in the manufacture of paper and paperboard can, in general terms, be split into three steps: pulp making, pulp processing, and paper/paperboard production. Paperboard sheets are thicker than paper sheets; paperboard is thicker than 0.3 mm. Generally speaking, however, paper and paperboard production processes are identical. First, a stock pulp mixture is produced by digesting a material into its fibrous constituents via chemical, mechanical, or a combination of chemical and mechanical means. In the case of wood, the most common pulping material, chemical pulping actions release cellulose fibers by selectively destroying the chemical bonds in the glue-like substance (lignin) that binds the fibers together. After the fibers are separated and impurities have been removed, the pulp may be bleached to improve brightness and processed to a form suitable for paper-making equipment. Currently one-fifth of all pulp and paper mills practice bleaching.[9] At the paper-making stage, the pulp can be combined with dyes, strength building resins, or texture adding filler materials, depending on its intended end product. Afterwards, the mixture is dewatered, leaving the fibrous constituents and pulp additives on a wire or wire-mesh conveyor. Additional additives may be applied after the sheet-making step. The fibers bond together as they are carried through a series of presses and heated rollers. The final paper product is usually spooled on large rolls for storage (see Exhibit 6).

The following discussion focuses mainly on pulping processes due to their importance in understanding industry environmental impacts and current industry regulatory classification schemes. If more information on papermaking processes is desired, the *Development Document for Proposed Effluent Limitations, Guidelines and Standards for the Pulp and Paper Industry, Point Source Category* (EPA-821-R-93-019) is recommended.

Exhibit 6: Simplified Flow Diagram: Integrated Mill (Chemical Pulping, Bleaching, and Paper Production)



(Source: Smook, GA *Handbook for Pulp & Paper Technologists*. Second Edition. Vancouver: Angus Wilde Publications, 1992.)

III.A.1. Pulp Manufacture

At the pulping stage, the processed furnish is digested into its fibrous constituents. The bonds between fibers may be broken chemically, mechanically, or by a combination of the techniques called semi-chemical pulping. The choice of pulping technique is dependent on the type of furnish and the desired qualities of the finished product, but chemical pulping is the most prevalent. Exhibit 7 presents an overview of the wood pulping types by the method of fiber separation, resultant fiber quality, and percent of 1990 U.S. pulp production. Many mills perform multiple pulping processes at the same site, most frequently non-deink secondary fiber pulping (61 percent of mills) and papergrade kraft pulping (24 percent of mills).[10] The three basic types of wood pulping processes 1) chemical pulping, 2) semi-chemical pulping, and 3) mechanical pulping are detailed below followed by a discussion of secondary fiber pulping techniques.

Exhibit 7: General Classification of Wood Pulping Processes

Process Category	*Fiber Separation Method*	*Fiber Quality*	*Examples*	*% of Total 1993 US Wood Pulp Production**
Mechanical	Mechanical energy	Short, weak, unstable, impure fibers	Stone groundwood, refiner mechanical pulp	10%
Semi-chemical	Combination of chemical and mechanical treatments	"Intermediate" pulp properties (some unique properties)	High-yield kraft, high-yield sulfite	6%
Chemical	Chemicals and heat	Long, strong, stable fibers	Kraft, sulfite, soda	84%

*American Forest and Paper Association, 1994 Statistics, Data Through 1993. Washington, D.C.:AF&PA, 1994.

Source: Smook, G.A. *Handbook for Pulp & Paper Technologists*. Second edition. Vancouver: Angus Wilde Publications, 1992.

A variety of technologies and chemicals are used to manufacture pulp, but most pulp manufacturing systems contain the following process sequence:

Exhibit 8: Pulp Manufacturing Process Sequence

Process Sequence	Description
Fiber Furnish Preparation and Handling	Debarking, slashing, chipping of wood logs and then screening of wood chips/secondary fibers (some pulp mills purchase chips and skip this step)
Pulping	Chemical, semi-chemical, or mechanical breakdown of pulping material into fibers
Pulp Processing	Removal of pulp impurities, cleaning and thickening of pulp fiber mixture
Bleaching	Addition of chemicals in a staged process of reaction and washing increases whiteness and brightness of pulp, if necessary
Stock Preparation	Mixing, refining, and addition of wet additives to add strength, gloss, texture to paper product, if necessary

Overall, most of the pollutant releases associated with pulp and paper mills occur at the pulping and bleaching stages where the majority of chemical inputs occur.

Furnish Composition

Furnish is the blend of fibrous materials used to make pulp. According to the *1990 National Census of Pulp, Paper, and Paperboard Manufacturing Facilities*, the most commonly used furnish material is wood; it is used in some form by approximately 95 percent of pulp and paper manufacturers. Overall, wood furnish averages approximately 50 percent of pulp content industry-wide.

The major source of fiber for paper products comes from the vegetative tissues of vascular plants. Although almost any vascular plant could be used for paper production, the economics of scale require a high fiber yield for paper manufacture. The principle source of paper-making fibers in the United States is wood from trees, the largest vascular plants available. The fibrous particles used to make paper are made of cellulose, a primary component of the cell walls of vascular plant tissues. The cellulose fibers must be removed from a chemical matrix (e.g., lignin, hemicelluloses, and resins) and result in a mixture of relatively pure fibers.

Wood used to make pulp can be in a variety of forms and types. Wood logs, chips, and sawdust are used to make pulp. Due to different physical and chemical properties, however, certain pulping processes are most efficient on specific wood types (see **Pulping**). The type of wood used can also make a difference in the final characteristics of the pulp. In general, softwood fibers are longer than those from hardwood and have thinner cell walls. The longer fibers of softwood promote inter-fiber bonding and produce papers of greater strength.

Secondary fibers comprise the next most common furnish constituent. Secondary fibers consist of pre-consumer fibers (e.g., mill waste fibers) and post-consumer fiber. Post-consumer fiber sources are diverse, but the most common are newsprint and corrugated boxes (See Exhibit 9). Although secondary fibers are not used in as great a proportion as wood furnish, approximately 70 percent of pulp and paper manufacturers use some secondary fibers in their pulp production and approximately 200 mills (approximately 40 percent of total number of mills) rely exclusively on secondary fibers for their pulp furnish.[11] Office of Water estimates place the number of mills relying completely on secondary fibers as a furnish source at 285, approximately 50 percent of all mills.[12] Secondary fibers must be processed to remove contaminants such as glues or bindings, but, depending on the end product, may or may not be processed to remove ink contaminants or brighten the pulp.

Secondary fiber use is increasing in the pulp and paper industry due to consumer demand for products made from recycled paper and a lack of adequate virgin fiber (see **Bleaching**). Within the secondary fiber category, consumption of fiber from recovered paper is growing more than twice as fast as overall fiber consumption.[13] The utilization of secondary fibers, expressed as a percentage of the total fibers used to make pulp, is at approximately 30 percent and is climbing slowly.[14] In a resource-deficient country such as Japan, the secondary fiber utilization rate is at about 50 percent, whereas the average utilization rate in Europe is approximately 40 percent. Due to losses of fiber substance and strength during the recycling process, a 50 percent utilization rate is considered the present maximum overall utilization rate for fiber recycling.[15]

In 1992, corrugated containers comprised about 50 percent of the secondary fiber used in paper and paperboard production. Secondary fiber sources are seldom used as feedstocks for high quality or grade paper products. Contaminants (e.g., inks, paper colors) are often present, so production of low-purity products is often cost-effective use of secondary fibers, although decontamination technologies are available. Approximately 75 percent of all secondary fiber in North America is presently used for multi-ply paperboard or the corrugating paper used to manufacture corrugated cardboard. Over the next decade, an increasing proportion of the total amount will be deinked for newsprint or other higher-quality uses.

Exhibit 9: Relative Wastepaper Usage as Secondary Fiber in 1992

Paper Type	***% of Total Wastepaper Usage in 1992***
Mixed Paper	13%
Old Newspaper	17%
Old Corrugated Cardboard	49%
Pulp Substitutes	11%
High-grade Deinked	10%

Source: American Forest and Paper Association, *1994 Statistics, Data Through 1993*. Washington, D.C.:AF&PA, 1994.

Other types of furnish include cotton rags and linters, flax, hemp, bagasse, tobacco, and synthetic fibers such as polypropylene. These substances are not used widely, however, as they are typically for low volume, specialty grades of paper.

The types of furnish used by a pulp and paper mill depend on the type of product produced and what is readily available. Urban mills use a larger proportion of secondary fibers due to the post-consumer feedstock close at hand. More rurally located mills are usually close to timber sources and thus may use virgin fibers in greater proportion.

Furnish Preparation

Furnish is prepared for pulp production by a process designed to supply a homogenous pulping feedstock. In the case of roundwood furnish (logs), the logs are cut to manageable size and then debarked. At pulp mills integrated with lumbering facilities, acceptable lumber wood is removed at this stage. At these facilities, any residual or waste wood from lumber processing is returned to the chipping process; in-house lumbering rejects can be a significant source of wood furnish at a facility. The bark of those logs not fit for lumber is usually either stripped mechanically or hydraulically with high powered water jets in order to prevent contaminantion of pulping operations. Depending on the moisture content of the bark, it may then be burned for energy production. Hydraulic debarking methods may require a drying step before burning. Usually, hydraulically removed bark is collected in a water flume, dewatered, and pressed before burning. Treatment of wastewater from this process is difficult and costly, however, whereas dry debarking methods can channel the removed bark directly into a furnace.[16] If not burned for energy production, bark can be used for mulch, ground cover, or as an ingredient in charcoal.

Debarked logs are cut into chips of equal size by chipping machines. Chippers usually produce uniform wood pieces 20 mm long in the grain direction and 4 mm thick. The chips are then put on a set of vibrating screens to remove those that are too large or small. Large chips stay on the top screens and are sent to be recut, while the smaller chips are usually burned with bark. Certain mechanical pulping processes, such as stone groundwood pulping, use roundwood; however, the majority of pulping operations require wood chips. Non-wood fibers are handled in ways specific to their composition. Steps are always taken to maintain fiber composition and thus pulp yield.

Chemical Pulping

Chemical pulps are typically manufactured into products that have high-quality standards or require special properties. Chemical pulping degrades wood by dissolving the lignin bonds holding the cellulose fibers together. Generally, this process involves the cooking/digesting of wood chips in aqueous chemical solutions at elevated temperatures and pressures. There are two major types of chemical pulping currently used in the U.S.: 1) kraft/soda pulping and 2) sulfite pulping. These processes differ primarily in the chemicals used for digesting. The specialty paper products rayon, viscose, acetate, and cellophane are made from dissolving pulp, a variant of standard kraft or sulfite chemical pulping processes.

Kraft pulping (or sulfate) processes produced approximately 80 percent of all US pulp tonnage during 1993 according to the American Forest and Paper Association (AF&PA) and other industry sources. According to EPA industry surveys, approximately 30 percent of all pulp and paper mills use the kraft process for some portion of pulp manufacture.[17] The

success of the process and its widespread adoption are due to several factors. First, because the kraft cooking chemicals are selective in their attack on wood constituents, the pulps produced are notably stronger than those from other processes (i.e., Kraft is German for "strength"). The kraft process is also flexible, in so far as it is amenable to many different types of raw materials (i.e., hard or soft woods) and can tolerate contaminants frequently found in wood (e.g., resins). Lignin removal is high in the kraft process, up to 90 percent- allowing high levels of bleaching without pulp degradation due to delignification (see **Pulp Bleaching**). Finally, the chemicals used in kraft pulping are readily recovered within the process, making it very economical and reducing potential environmental releases (See *Chemical Recovery Systems* below).
The kraft process uses a sodium-based alkaline pulping solution (liquor) consisting of sodium sulfide (Na_2S) and sodium hydroxide (NaOH) in 10 percent solution. This liquor (white liquor) is mixed with the wood chips in a reaction vessel (digester). The output products are separated wood fibers (pulp) and a liquid that contains the dissolved lignin solids in a solution of reacted and unreacted pulping chemicals (black liquor). The black liquor undergoes a chemical recovery process (see *Chemical Recovery Systems*) to regenerate white liquor for the first pulping step. Overall, the kraft process converts approximately 50 percent of input furnish into pulp.

The kraft process evolved from the soda process. The soda process uses an alkaline liquor of only sodium hydroxide (NaOH). The kraft process has virtually replaced the soda process due to the economic benefits of chemical recovery and improved reaction rates (the soda process has a lower yield of pulp per pound of wood furnish than the kraft process).

Sulfite pulping was used for approximately 4 percent of U.S. pulp production in 1993 (AF&PA). Softwood is the predominant furnish used in sulfite pulping processes. However, only non-resinous species are generally pulped. The sulfite pulping process relies on acid solutions of sulfurous acid (H_2SO_3) and bisulfite ion (HSO_3^-) to degrade the lignin bonds between wood fibers.

Sulfite pulps have less color than kraft pulps and can be bleached more easily, but are not as strong. The efficiency and effectiveness of the sulfite process is also dependent on the type of wood furnish and the absence of bark. For these reasons, the use of sulfite pulping has declined in comparison to kraft pulping over time.

Semi-chemical pulping

Semi-chemical pulping comprised 6 percent of U.S. pulp production in 1993 (AF&PA). Semi-chemical pulp is often very stiff, making this process common in corrugated container manufacture. This process primarily uses hardwood as furnish.

The semi-chemical process involves partial digestion of furnish in a weak chemical solution followed by mechanical refining for fiber separation. At most, the digestion step in the semi-chemical pulping process consists of heating pulp in sodium sulfite (Na_2SO_3) and sodium carbonate (Na_2CO_3) Other semi-chemical processes include the Permachem process and the two-stage vapor process. The yield of semi-chemical pulping ranges from 55 to 90 percent, depending on the process used, but pulp residual lignin content is also high so bleaching is more difficult.

Mechanical pulping

Mechanical pulping accounted for 10 percent of U.S. pulp production in 1993 (AF&PA). Mechanically produced pulp is of low strength and quality. Such pulps are used principally for newsprint and other non-permanent paper goods. Mechanical pulping uses physical pressure instead of chemicals to separate furnish fibers. Processes include: 1) stone groundwood, 2) refiner mechanical, 3) thermo-mechanical, 4) chemi-mechanical, and 5) chemi-thermo-mechanical. Pulp yields are high, up to 95 percent when compared to chemical pulping yields of 45- 50 percent, but energy usage is also high. To offset its weakness, mechanical pulp is often blended with chemical pulp.

Secondary fiber pulping

Secondary fiber pulping accounted for approximately 30 percent of domestic pulp production in 1992 (AF&PA). More than 200 mills rely exclusively on recovered paper for pulp furnish.[18] In addition, consumption of fiber from recovered paper is growing more than twice as fast as overall fiber consumption. Secondary fibers are usually presorted before they are sold to a pulp and paper mill. If not, secondary fibers are processed to remove contaminants before pulping occurs. According to the USEPA 1990 National Census of Pulp, Paper, and Paperboard Manufacturing Facilities, approximately 70 percent of all pulp and paper mills process secondary fiber at their facilities in some way. Common contaminants consist of adhesives, coatings, polystyrene foam, dense plastic chips, polyethylene films, wet strength resins, and synthetic fibers. In some cases, contaminants of greater density than the desired secondary fiber are removed by centrifugal force while light contaminants are removed by flotation systems. Centri cleaners are also used to remove material less dense than fibers (wax and plastic particles).[19]

Inks, another contaminant of secondary fibers, may be removed by heating a mixture of secondary fibers with surfactants. The removed inks are then dispersed in an aqueous media to prevent redeposition on the fibers. Continuous solvent extraction has also been used to recover fibers from paper and board coated with plastics and/or waxes. Only 8 percent of U.S. mills engaged in deinking of secondary fibers as of 1993. Deinking capacity is rapidly increasing, however. There are currently 83 recovered paper deinking facilities in operation in the U.S. with another 44 planned for construction or start-up between 1995 and 1997.[20]

Secondary fiber pulping is a relatively simple process. The most common pulper design consists of a large container filled with water, which is sometimes heated, and the recycled pulp. Pulping chemicals (e.g., sodium hydroxide, NaOH) are often added to promote dissolution of the paper or board matrix. The source fiber (corrugated containers, mill waste, etc.) is dropped into the pulper and mixed by a rotor. Debris and impurities are removed by two mechanisms: a ragger and a junker. The ragger withdraws strings, wires, and rags from the stock secondary fiber mixture. A typical ragger consists of a few "primer wires" that are rotated in the secondary fiber slurry. Debris accumulates on the primer wires, eventually forming a "debris rope" which is then removed. Heavier debris are separated from the mixture by centrifugal force and fall into a pocket on the side of the pulper. The junker consists of a grappling hook or elevator bucket. Heat, dissolution of chemical bonds, shear forces created by stirring and mixing, and grinding by mechanical equipment may serve to dissociate fibers and produce a pulp of desired consistency in various pulping machinery.

Contaminant removal processes depend on the type and source of secondary fiber to be pulped. Mill paper waste can be easily repulped with minimal contaminant removal. Recycled post-consumer newspaper, on the other hand, may require extensive contaminant removal, including deinking, prior to reuse. Overall, the quality of secondary fiber strongly affects the quality of the paper products. As noted in *Furnish Composition*, above, approximately 75 percent of all secondary fiber in North America is presently used for multi-ply paperboard or the corrugating paper used to manufacture corrugated cardboard. Over the next decade, an increasing proportion of the total amount will be deinked for newsprint or other higher-quality uses.

III.A.2. Pulp Processing

After pulp production, pulp processing removes impurities, such as uncooked chips, and recycles any residual cooking liquor via the washing process (Exhibit 10). Pulps are processed in a wide variety of ways, depending on the method that generated them (e.g., chemical, semi-chemical). Some pulp processing steps that remove pulp impurities include screening, defibering, and deknotting. Pulp may also be thickened by removing a portion of the water. At additional cost, pulp may be blended to insure product uniformity. If pulp is to be stored for long periods of time, drying steps are necessary to prevent fungal or bacterial growth.

Residual spent cooking liquor from chemical pulping is washed from the pulp using brown stock washers. Efficient washing is critical to maximize return of cooking liquor to chemical recovery (See *Chemical Recovery Systems* below) and to minimize carryover of cooking liquor (known as brown stock washing loss) into the bleach plant, because excess cooking liquor increases consumption of bleaching chemicals. Specifically, the dissolved organic compounds (lignins and hemicelluloses) contained in the liquor will bind to bleaching chemicals and thus increase bleach chemical consumption. In addition, these organic compounds function as precursors to chlorinated organic compounds (e.g., dioxins, furans), increasing the probability of their formation. The most common washing technology is rotary vacuum washing, carried out sequentially in two or four washing units. Other washing technologies include diffusion washers, rotary pressure washers, horizontal belt filters, wash presses, and dilution/extraction washers.

Pulp screening, removes remaining oversized particles such as bark fragments, oversized chips, and uncooked chips. In *open* screen rooms, wastewater from the screening process goes to wastewater treatment prior to discharge. In *closed loop* screen rooms, wastewater from the process is reused in other pulping operations and ultimately enters the mill's chemical recovery system. Centrifugal cleaning (also known as liquid cyclone, hydrocyclone, or centricleaning) is used after screening to remove relatively dense contaminants such as sand and dirt. Rejects from the screening process are either repulped or disposed of as solid waste.

Chemical Recovery Systems

The chemical recovery system is a complex part of a chemical pulp and paper mill and is subject to a variety of environmental regulations.

Chemical recovery is a crucial component of the chemical pulping process: it recovers process chemicals from the spent cooking liquor for reuse. The chemical recovery process has important financial and environmental benefits for pulp and paper mills. Economic benefits include savings on chemical purchase costs due to regeneration rates of process chemicals approaching 98 percent, and energy generation from pulp residue burned in a recovery furnace.[21] Environmental benefits include the recycle of process chemicals and lack of resultant discharges to the environment.

Both kraft and sulfite chemical pulping processes use chemical recovery systems, although the actual chemical processes at work differ markedly. Due to its widespread usage, only the kraft chemical recovery system will be covered in depth in this document. Sulfite chemical recovery systems are discussed briefly at the end of this section.

Kraft Chemical Recovery Systems

The kraft chemical recovery process has not been fundamentally changed since its patent issue in 1884, but has been refined into a stepwise progression of chemical reactions. New technologies are under development, however, as two black liquor gasification processes (Chemtrec and MTCI) were brought to the pilot stage at pulp mill sites in 1991.

The precise details of the chemical processes at work in the chemical recovery process can be found in Smook, *Handbook for Pulp and Paper Technologists,* 2nd Edition, 1992 and will not be discussed here. The kraft chemical recovery process consists of the following general steps:

<u>Black liquor concentration</u>

Residual weak black liquor from the pulping process is concentrated by evaporation to form "strong black liquor." After brown stock washing (See *Pulp Processing*) in the pulping process the concentration of solids in the weak black liquor is approximately 15 percent; after the evaporation process, solids concentration can range from 60 - 80 percent. In some older facilities, the liquor then undergoes oxidation for odor reduction. The oxidation step is necessary to reduce odor created when hydrogen sulfide is stripped from the liquor during the subsequent recovery boiler burning process. Almost all recovery furnaces installed since 1968 have non-contact evaporation processes that avoid these problems, however, so oxidation processes are not usually seen in newer mills. Common modern evaporator types include multiple effect evaporators as well as a variety of supplemental evaporators. Odor problems with the kraft process have been the subject of control measures (See Section II.B. Raw Material Inputs and Pollution Outputs in the Production Line for more information).

Recovery boiler

The strong black liquor from the evaporators is burned in a recovery boiler. In this crucial step in the overall kraft chemical recovery process, organic solids are burned for energy and the process chemicals are removed from the mixture in molten form. Molten inorganic process chemicals (smelt) flow through the perforated floor of the boiler to water-cooled spouts and dissolving tanks for recovery in the recausticizing step.

Energy generation from the recovery boiler is often insufficient for total plant needs, however, so facilities augment recovery boilers with fossil-fuel-fired and wood-waste-fired boilers (hogged fuel) to generate steam and often electricity. Industry-wide, the utilization of pulp wastes, bark, and other papermaking residues supplies 56 percent of the energy requirements of pulp and paper companies.[22] (See III.A.3. Energy Generation for more information).

Recausticizating

Smelt is recausticized to remove impurities left over from the furnace and to convert sodium carbonate (Na_2CO_3) into active sodium hydroxide (NaOH) and sodium sulfide (Na_2S). The recausticization procedure begins with the mixing of smelt with "weak" liquor to form green liquor, named for its characteristic color. Contaminant solids, called dregs, are removed from the green liquor, which is mixed with lime (CaO). After the lime mixing step, the mixture, now called white liquor due to its new coloring, is processed to remove a layer of lime mud ($CaCO_3$) that has precipitated. The primary chemicals recovered are caustic (NaOH) and sodium sulfide (Na_2S). The remaining white liquor is then used in the pulp cooking process. The lime mud is treated to regenerate lime in the calcining process.

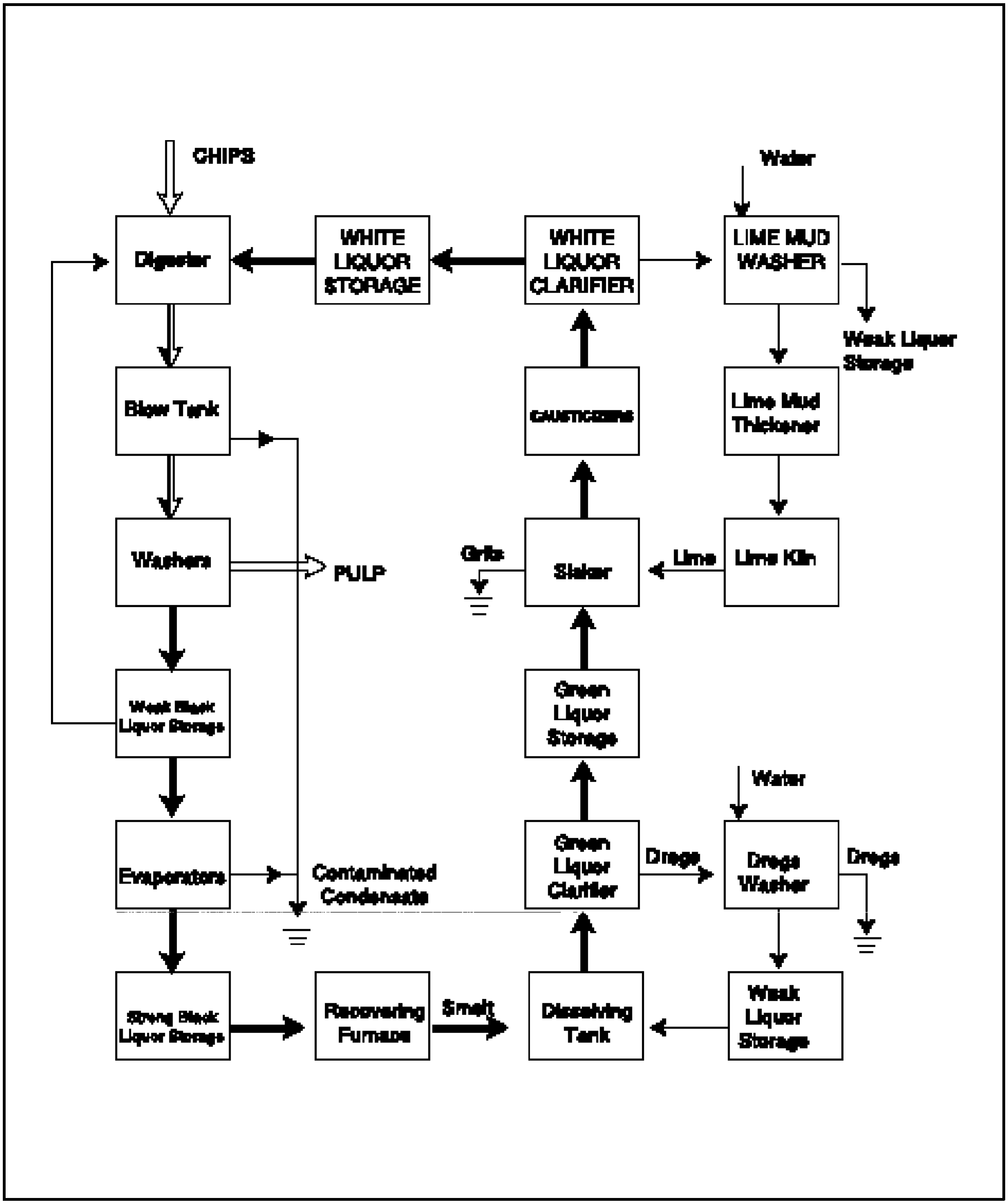
Calcining

In the calcining process, the lime mud removed from the white liquor is burned to regenerate lime for use in the lime mixing step. The vast majority of mills use lime kilns for this process, although a few mills now use newer fluidized bed systems.

Sulfite Chemical Recovery Systems

There are a variety of sulfite chemical pulping recovery systems in use today. Heat and sulfur can be recovered from all liquors generated, however the base chemical can only be recovered from magnesium and sodium base processes (See Smook, 1992 for more information).

Exhibit 10: The Kraft Pulping Process (with chemical recovery)



(Source: Smook, G.A. *Handbook for Pulp & Paper Technologists*. Second Edition. Vancouver: Angus Wilde Publications, 1992.)

III.A.3. Bleaching

Bleaching is defined as any process that chemically alters pulp to increase its brightness. Bleached pulps create papers that are whiter, brighter, softer, and more absorbent than unbleached pulps. Bleached pulps are used for products where high purity is required and yellowing (or color reversion) is not desired (e.g. printing and wrapping papers, food contact papers). Unbleached pulp is typically used to produce boxboard, linerboard, and grocery bags. Of the approximately 72 million tons of pulp (including recycled pulp) used in paper production in the United States in 1993, approximately 50 percent percent was bleached in some fashion.[23]

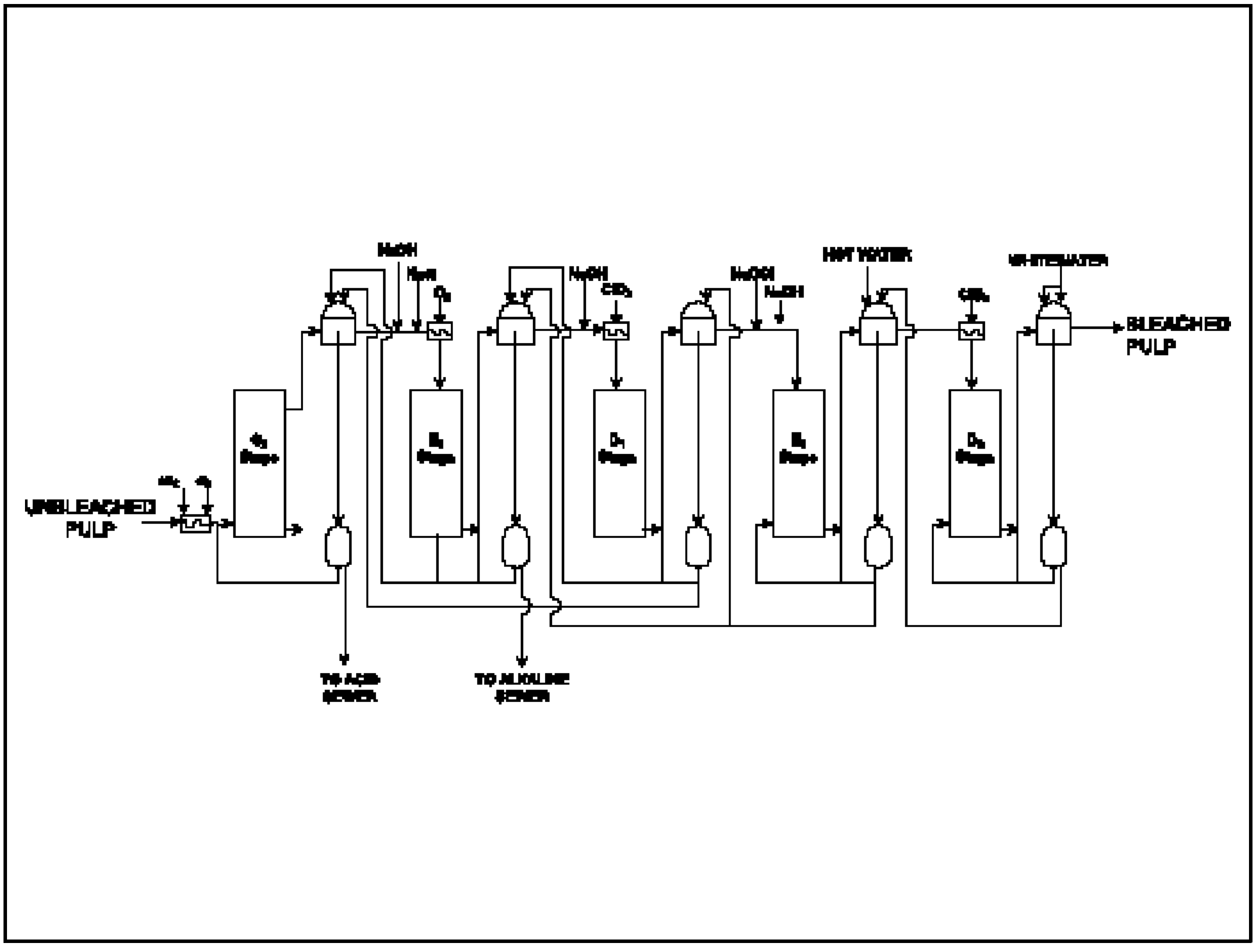
Any type of pulp may be bleached, but the type(s) of fiber furnish and pulping processes used, as well as the desired qualities and end use of the final product, greatly affect the type and degree of pulp bleaching possible. Printing and writing papers comprise approximately 60 percent of bleached paper production. The lignin content of a pulp is the major determinant of its bleaching potential. Pulps with high lignin content (e.g., mechanical or semi-chemical) are difficult to bleach fully and require heavy chemical inputs. Excessive bleaching of mechanical and semi-chemical pulps results in loss of pulp yield due to fiber destruction. Chemical pulps can be bleached to a greater extent due to their low (10 percent) lignin content.

For more information, the *Summary of Technologies for the Control and Reduction of Chlorinated Organics from the Bleached Chemical Pulping Subcategories of the Pulp and Paper Industry* 1990 from the Office of Water Regulations and Standards is recommended. Typical bleaching processes for each pulp type are detailed below.

Chemical pulps are bleached in traditional bleach plants (see Exhibit 11) where the pulp is processed through three to five stages of chemical bleaching and water washing. The number of cycles is dependent on the whiteness desired, the brightness of initial stock pulp, and plant design.

Bleaching stages generally alternate between acid and alkaline conditions. Chemical reactions with lignin during the acid stage of the bleaching process increase the whiteness of the pulp. The alkaline extraction stages dissolve the lignin/acid reaction products. At the washing stage, both solutions and reaction products are removed. Chemicals used to perform the bleaching process must have high lignin reactivity and selectivity to be efficient. Typically, 4-8 percent percent of pulp is lost due to bleaching agent reactions with the wood constituents cellulose and hemicellulose, but, these losses can be as high as 18 percent.

Exhibit 11: Typical Bleach Plant



(Source: U.S. EPA, Development Document for Proposed Effluent Limitations Guidelines and Standards for the Pulp, Paper, and Paperboard Point Source Category. October 1993.)

The most common chemicals used in the bleaching process are sodium hydroxide, elemental chlorine, and chlorine dioxide. The use of chlorine dioxide in the bleach process has steadily increased relative to molecular chlorine usage due to its reduction in the formation of chlorinated organics in bleach plant effluent and lower bleach plant chemical consumption. Common bleaching chemicals are presented below along with the approximate percentage of mills using them, their chemical formulae, and bleach chemical code letter:

Exhibit 12: Common Chemicals Used in Bleaching Process

Bleaching Chemical	Approximate % of Mills[a]	Chemical Formula	Code Letter
Sodium Hydroxide	100%	$NaOH$	E
Elemental Chlorine	99%	Cl_2	C
Chlorine Dioxide	89%	ClO_2	D
Hypochlorite	69%	$HClO$, $NaOCl$, $Ca(OCl)_2$	H
Oxygen	64%	O_2	O
Hydrogen Peroxide	43%	H_2O_2	P
Sulfur Dioxide	10%	SO_2	S
Sulfuric Acid	9%	H_2SO_4	A

[a]Approximate percentage of total number of papergrade kraft, soda, and dissolving soda mills that bleach chemical wood pulp in traditional bleach plants; not based on amount of pulp bleached by mills.

Source: USEPA. *1990 National Census of Pulp, Paper, and Paperboard Manufacturing Facilities.* 1990.

Bleaching process descriptions commonly refer to chemical reaction stages by their chemical code letter. The following table represents the most common bleaching sequences used in the U.S. and Canada in 1991.

Exhibit 13: Bleaching Sequences

Sequence	Percent of Mills
C-E-D-E-D	38%
C-E-H-E-D	19%
C-E-H-D-E-D	13%
C-E-H, C-E-H-P	8%
Other (e.g., chlorine dioxide first stage)	22%

Source: *Multimedia Analysis of Alternative Pulp and Paper Technologies*, 1991.

The production of chlorinated pollutants such as dioxin as well as production of chloroform results from the bleaching of pulps with chlorine and chlorine derivatives. A variety of bleaching processes have been developed which may be chlorine free, where bleaching chemicals such as ozone (Z), oxygen (O), and peroxide (P), replace chlorine and chlorine derivatives. Currently, at least one U.S. mill uses ozone in its bleaching process and others are installing or actively considering ozone bleaching. Overall, there has been a recent major trend in the industry toward reductions in both the types and amount of chlorine and chlorine-containing chemicals used for pulp bleaching, such that the data presented in the above table may not fully represent the distribution of bleaching processes currently in use by the industry. Some changes include: in 1994 chlorine dioxide usage (in tons) was, for the first time, greater than elemental chlorine usage in the bleach process,[24] use of hypochlorite has diminished in response to concerns about chloroform emissions, chlorine injection process modifications have been made, and significant efforts have been made to improve delignification to minimize dioxin formation while reducing bleach chemical usage. Some of these delignification technologies include extended delignification during kraft pulping, solvent pulping, and pulping in the presence of the catalyst anthraquinone. Oxygen delignification is also used as a post-pulping method of increasing delignification. These processes can be more costly, lead to reduced pulp yield and strength, and be potential sources of other pollutants. Some positive aspects of these processes may include: lower bleach chemical costs, lower energy consumption, reduced toxicity, reduced color, and reduced BOD. Totally chlorine-free (TCF) bleaching of selected market grades of sulfite and kraft pulps has been demonstrated in Europe, but, as of October 1993, no commercial production of market grade high brightness softwood kraft pulps had been demonstrated in the United States. As of 1994, one mill has implemented a TCF process to produce mid to high brightness pulps. It should be noted, based on American Forest and Paper Association data, that 9 out of 10 pulp and paper mills currently in operation have non-detectable levels of dioxin in effluent.

Semi-chemical pulps are typically bleached with hydrogen peroxide (H_2O_2) in a bleach tower.

Mechanical pulps are bleached with hydrogen peroxide (H_2O_2) and/or sodium hydrosulfite (Na_2SO_3). Bleaching chemicals are either applied without separate equipment during the pulp processing stage (i.e., in-line bleaching), or in bleaching towers. Full bleaching of mechanical pulps is generally not practical due to bleaching chemical cost and the negative impact on pulp yield.

Deinked secondary fibers are usually bleached in a bleach tower, but may be bleached during the repulping process. Bleach chemicals may be added directly into the pulper. The following are examples of chemicals used to bleach deinked secondary fibers: hypochlorite ($HClO$, $NaOCl$, $Ca(OCl)_2$), hydrogen peroxide (H_2O_2), and hydrosulphite ($Na_2S_2O_4$).

III.A.4. Stock Preparation

At this final stage, the pulp is processed into the stock used for paper manufacture. Market pulp, which is to be shipped off-site to paper or paperboard mills, is processed little, if at all at this stage. Processing includes pulp blending specific to the desired paper product desired, dispersion in water, beating and refining to add density and strength, and addition of any necessary wet additives. Wet additives are used to create paper products with special properties or to facilitate the papermaking process. Wet additives include resins and waxes for water repellency, fillers such as clays, silicas, talc, inorganic/organic dyes for coloring, and certain inorganic chemicals (calcium sulfate, zinc sulfide, and titanium dioxide) for improved texture, print quality, opacity, and brightness.

III.A.5. Processes in Paper Manufacture

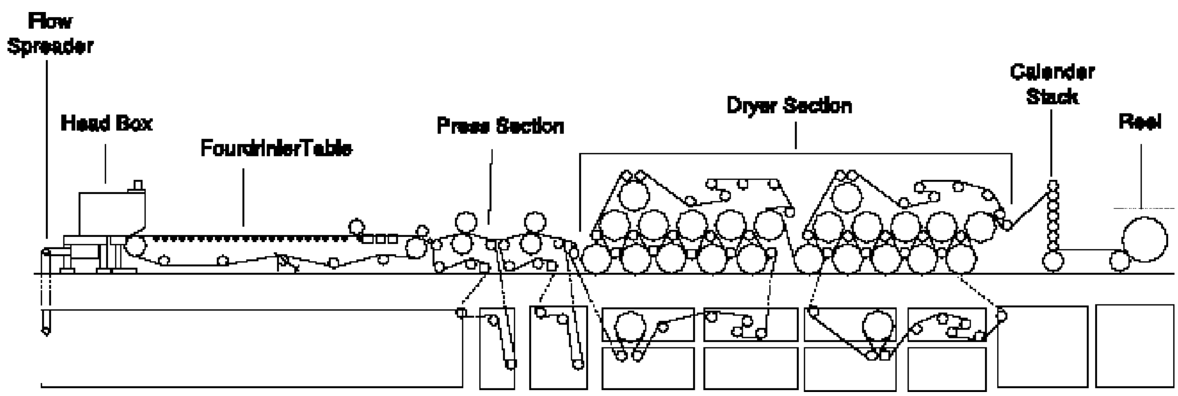
The paper and paperboard making process consists of the following general steps:

Exhibit 14: Paper and Paperboard Making Process	
Sequential Process	**Description**
Wet End Operations	Formation of paper sheet from wet pulp
Dry End Operations	Drying of paper product, application of surface treatments, spooling for storage

Wet End Operations

The processed pulp is converted into a paper product via a paper production machine, the most common of which is the Fourdrinier paper machine (see Exhibit 15). In the Fourdrinier system, the pulp slurry is deposited on a moving wire belt that carries it through the first stages of the process. Water is removed by gravity, vacuum chambers, and vacuum rolls. This waste water is recycled to the slurry deposition step of the process due to its high fiber content. The continuous sheet is then pressed between a series of rollers to remove more water and compress the fibers.

Exhibit 15: Fourdrinier Paper Machine



(Source: U.S. EPA, *Development Document for Proposed Effluent Limitations Guidelines and Standards for the Pulp, Paper and Paperboard Point Source Category.* October 1993.)

Dry End Operations

After pressing, the sheet enters a drying section, where the paper fibers begin to bond together as steam heated rollers compress the sheets. In the calender process the sheet is pressed between heavy rolls to reduce paper thickness and produce a smooth surface. Coatings can be applied to the paper at this point to improve gloss, color, printing detail, and brilliance. Lighter coatings are applied on-machine, while heavy coatings are performed off-machine. The paper product is then spooled for storage.

III.A.6. Energy Generation

Pulp and paper mill energy generation is provided in part from the burning of liquor waste solids in the recovery boiler, but other energy sources are needed to make up the remainder of mill energy needs. Over the last decade the pulp and paper industry has changed its energy generation methods from fossil fuels to a greater utilization of processes or process wastes. The increase in use of wood wastes from the wood handling and chipping processes depicted in Exhibit 16 below is one example of this industry-wide movement. During the 1972-1990 period, the proportion of total industry power generation from the combination of woodroom wastes, spent liquor solids, and other self-generation methods increased by approximately 15 percent, while fuel oil and natural gas use decreased 20 percent. Increases in purchased steam and coal use, made up the difference.

Power boilers at pulp and paper mills are sources of particulate emissions, SO_2, and NO_x. Pollutants emitted from chemical recovery boilers include SO_2, and total reduced sulfur compounds (TRS).

Exhibit 16: Estimated Energy Sources for the U.S. Pulp and Paper Industry, 1972, 1979, 1990 by percentages

Energy source	***1972***	***1979***	***1990***
Purchased steam	5.4	6.7	7.3
Coal	9.8	9.1	13.7
Fuel oil	22.3	19.1	6.4
Natural gas	21.5	17.8	16.4
Waste wood and wood chips (Hogged fuel) and bark	6.6	9.2	15.4
Spent liquor solids	33.7	37.3	39.4
Self-generated power	0.6	0.8	1.2

Source: American Paper Institute Data as presented in Smook, G.A. *Handbook for Pulp & Paper Technologists*. Second edition. Vancouver: Angus Wilde Publications, 1992.

III.B. Raw Material Inputs and Pollution Outputs in the Production Line

Pulp and paper mills use and generate materials that may be harmful to the air, water, and land: pulp and paper processes generate large volumes of wastewaters which might adversely affect freshwater or marine ecosystems, residual wastes from wastewater treatment processes may contribute to existing local and regional disposal problems, and air emissions from pulping processes and power generation facilities may release odors, particulates, or other pollutants. Major sources of pollutant releases in pulp and paper manufacture are at the pulping and bleaching stages respectively. As such, non-integrated mills (i.e., those mills without pulping facilities on-site) are not significant environmental concerns when compared to integrated mills or pulp mills.

Water

The pulp and paper industry is the largest industrial process water user in the U.S.[25] In 1988, a typical pulp and paper mill used 16,000 to 17,000 gallons of water per ton of pulp produced.[26] General water pollution concerns for pulp and paper mills are effluent solids, biochemical oxygen demand, toxicity, and color. Toxicity concerns arise from the presence of chlorinated organic compounds such as dioxins, furans, and others (collectively referred to as adsorbable organic halides, or AOX) in wastewaters after the chlorination/extraction sequence.

Due to the large volumes of water used in pulp and paper processes, virtually all U.S. mills have primary and secondary wastewater treatment systems installed to remove particulate and biochemical oxygen demand (BOD) produced in the manufacturing processes. These systems also provide significant removals (e.g., 30-70 percent) of other important parameters such as adsorbable organic halides (AOX) and chemical oxygen demand (COD).

The major sources of effluent pollution in a pulp and paper mill are presented in Exhibit 17.

Exhibit 17: Common Water Pollutants From Pulp and Paper Processes

Source	*Effluent characteristics*
Water used in wood handling/debarking and chip washing	Solids, BOD, color
Chip digester and liquor evaporator condensate	Concentrated BOD, can contain reduced sulfur
"White waters" from pulp screening, thickening, and cleaning	Large volume of water with suspended solids, can have significant BOD
Bleach plant washer filtrates	BOD, color, chlorinated organic compounds
Paper machinewater flows	Solids, often precipitated for reuse
Fiber and liquor spills	Solids, BOD, color

Source: Smook, G.A. *Handbook for Pulp & Paper Technologists*. Second edition. Vancouver: Angus Wilde Publications, 1992.

Screening and cleaning operations during the pulp processing stage are usually sources of large volumes of wastewaters. This effluent stream, called white water due to its characteristic color, can contain significant BOD if washing efficiency is low and is always a source of suspended solids from wood particles. Similar white water wastes are also produced during the papermaking process. White waters can be reused to dilute furnish mixtures or the solids can be collected for reuse. Fiber and liquor spills can also be a source of mill effluent. Typically, spills are captured and pumped to holding areas to reduce chemical usage through spill reuse and to avoid loadings on facility wastewater treatment systems. Separate pump systems recycle recoverable materials into the process cycle. The condensates from chip digesters and chemical recovery evaporators are a low-volume, but high BOD effluent source. Some of these condensates contain reduced sulfur compounds.

Wastewater treatment systems can be a significant source of cross-media pollutant transfer. For example, waterborne particulate and some chlorinated compounds settle or absorb onto treatment sludge and other compounds may volatilize during the wastewater treatment process.

Air

The following table is an overview of the major types and sources of air pollutant releases from various pulp and paper processes:

Exhibit 18: Common Air Pollutants From Pulp and Paper Processes

Source	***Type***
Kraft recovery furnace	Fine particulates
Fly ash from hog fuel and coal-fired burners	Course particulates
Sulfite mill operations	Sulfur oxides
Kraft pulping and recovery processes	Reduced sulfur gasses
Chip digesters and liquor evaporation	Volatile organic compounds
All combustion processes	Nitrogen oxides

Source: Smook, G.A. *Handbook for Pulp & Paper Technologists*. Second edition. Vancouver: Angus Wilde Publications, 1992.

Water vapors are the most visible air emission from a pulp and paper mill, but are not usually regulated unless they are a significant obscurement or climate modifier.

Pulp and paper mill power boilers and chip digesters are generic pulp and paper mill sources of air pollutants such as particulates and nitrogen oxides. Chip digesters and chemical recovery evaporators are the most concentrated sources of volatile organic compounds. The chemical recovery furnace is a source of fine particulate emissions and sulfur oxides. In the kraft process, sulfur oxides are a minor issue in comparison to the odor problems created by four reduced sulfur gasses, called together total reduced sulfur (TRS): hydrogen sulfide, methyl mercaptan, dimethyl sulfide, and dimethyl disulfide. The TRS emissions are primarily released from wood chip digestion, black liquor evaporation, and chemical recovery boiler processes. TRS compounds create odor nuisance problems at lower concentrations than sulfur oxides: odor thresholds for TRS compounds are approximately 1000 times lower than that for sulfur dioxide. Humans can detect some TRS compounds in the air as a "rotten egg" odor at as little as 1 ppb.

Pulp and paper mills have made significant investments in pollution control technologies and processes. According to industry sources, the pulp and paper industry spent more than $1billion per year from 1991-1994 on environmental capital expenditures. In 1991 and 1992, this represented 20 percent of total capital expenditures.[27] Chemical recovery and recycling systems in the chemical pulping process significantly reduce pollutant outputs while providing substantial economic return due to recovery of process chemicals. Chemical recovery is necessary for the basic economic viability of the kraft process. According to EPA sources, all kraft pulp mills worldwide have chemical recovery systems in place. Some sulfite mills, however, still do not have recovery systems in place. Scrubber system particulate "baghouses" or electrostatic precipitators (ESPs) are are often mill air pollution control components.

Residual Wastes

The significant residual waste streams from pulp and paper mills include bark, wastewater treatment sludges, lime mud, lime slaker grits, green liquor dregs, boiler and furnace ash, scrubber sludges, and wood processing residuals. Because of the tendency for chlorinated organic compounds (including dioxins) to partition from effluent to solids, wastewater treatment sludge has generated the most significant environmental concerns for the pulp and paper industry. To a lesser extent, concern has also been raised over whether chlorinated organics are partitioned into pulp products, a large portion of which become a post-consumer residual waste.

With the exception of bark, wastewater treatment sludge is the largest volume residual waste stream generated by the pulp and paper industry. Sludge generation rates vary widely among mills. For example, bleached kraft mills surveyed as part of EPA's 104-Mill Study reported sludge generation that ranged from 14 to 140 kg sludge per ton pulp.[28] Total sludge generation for these 104 mills was 2.5 million dry metric tons per year, or an average of approximately 26,000 dry metric tons per year per plant. Pulpmaking operations are responsible for the bulk of sludge wastes, although treatment of papermaking effluents also generates significant sludge volumes. For the majority of pulp and integrated mills that operate their own wastewater treatment systems, sludges are generated onsite. A small number of pulp mills, and a much larger proportion of papermaking establishments, discharge effluents to publicly-owned wastewater treatment works (POTWs).

Potential environmental hazards from wastewater sludges are associated with trace constituents (e.g., chlorinated organic compounds) that partition from the effluent into the sludge. The 1988 results of the "104-Mill Study" showed that dioxins and furans were present in bleached pulp mill sludges, resulting in calls to regulate both landfill disposal and land application of such sludges (See Federal Regulations section). Landfill and surface impoundment disposal are most often used for wastewater treatment sludge; in 1988 only eleven of 104 bleached kraft mills disposed of any sludge through land application or conversion to sludge-derived products (e.g., compost, animal bedding).

Process Inputs and Pollutant Outputs

Kraft chemical pulping and traditional chlorine-based bleaching are both commonly used and may generate significant pollutant outputs. Kraft pulping processes produced approximately 80 percent of total US pulp tonnage during 1993 according to the American Forest and Paper Association (AF&PA) and other industry sources. While the use of traditional chlorine bleaching is in decline, a significant proportion of kraft mills currently use the process.

Pollutant outputs from mechanical, semi-chemical, and secondary fiber pulping are small when compared to kraft chemical pulping. In the pulp and paper industry, the kraft pulping process is the most significant source of air pollutants. Pollutant outputs from chlorine bleaching, the chlorinated by-products chloroform and dioxin, are particular problems due to their persistence, non-biodegradability, and toxicity. The following table (Exhibit 19) and Exhibits illustrate the process inputs and pollutant outputs for a pulp and paper mill using kraft chemical pulping and traditional chlorine-based bleaching. Currently, extensive chlorine dioxide substitution is practiced in many bleaching processes in place of traditional chlorine bleaching. The process outlined below produces a large portion of U.S. pulp.

Exhibit 19 presents the process steps, material inputs, and major pollutant outputs (by media) of a kraft pulp mill practicing traditional chlorine bleaching. The following resources are recommended for pollutant production data (e.g., pounds of BOD per ton of pulp produced) for those pollutants presented in Exhibit 19:

- *Pollution Prevention Technologies for the Bleached Kraft Segment of the U.S. Pulp and Paper Industry*. August 1993. (EPA-600-R-93-110)

- *Development Document for Proposed Effluent Limitations Guidelines and standards for the Pulp, Paper, and Paperboard Point Source Category*. October 1993. (EPA-821-R-93-019)

- *Pulp, Paper and Paperboard Industry - Background Information for Proposed Air Emission Standards Manufacturing Processes at Kraft, Sulfite, Soda, and Semi-Chemical Mills, NESHAP.* October 1993. (EPA-453-R-93-050a)

Exhibit 20 is a process flow diagram of the kraft process, illustrating chemical pulping, power recovery, and chemical recovery process inputs and outputs. Exhibit 21 is a schematic of characteristic air emission sources from a kraft mill.

Exhibit 19: Kraft Chemical Pulped-Chlorine Bleached Paper Production

Process Step	Material Inputs	Process Outputs	Major Pollutant Outputs*	Pollutant Media
Fiber Furnish Preparation	Wood logs Chips Sawdust	Furnish chips	dirt, grit, fiber, bark	Solid
			BOD	Water
			TSS	
Chemical Pulping Kraft process	Furnish chips	Black liquor (to chemical recovery system), pulp (to bleaching/processing)	resins, fatty acids	Solid
			color	Water
			BOD	
			COD	
			AOX	
			VOCs (terpenes, alcohols, phenols, methanol, acetone, chloroform, MEK)	
			VOCs (terpenes, alcohols, phenols, methanol, acetone, chloroform, MEK)	Air
	Cooking chemicals: sodium sulfide (Na_2S), NaOH, white liquor (from chemical recovery)		reduced sulfur compounds (TRS)	
			organo-chlorine compounds (e.g., 3,4,5- trichloroguaiacol)	

Exhibit 19: Kraft Chemical Pulped-Chlorine Bleached Paper Production

Process Step	Material Inputs	Process Outputs	Major Pollutant Outputs*	Pollutant Media
Bleaching	Chemical pulp	Bleached pulp	dissolved lignin and carbohydrates	Water
			color	
			COD	
			AOX	
			inorganic chlorine compounds (e.g., chlorate (ClO_3^-))[1]	
	Elemental chlorine (Cl_2), chlorine containing compounds		organo-chlorine compounds (e.g., dioxins, furans, chlorophenols)	
	Hypochlorite (HClO, NaOCl, $Ca(OCl)_2$) Chlorine dioxide (ClO_2)		VOCs (acetone, methylene chloride, chloroform, MEK, carbon disulfide, chloromethane, trichloroethane)	Air / Water
Papermaking	Additives, Bleached/ Unbleached pulp	Paper/paperboard product	particulate wastes	Water
			organic compounds	
			inorganic dyes	
			COD	
			acetone	
Wastewater Treatment Facilities	Process wastewaters	Treated effluent	sludge	Solid
			VOCs (terpenes, alcohols, phenols, methanol, acetone, chloroform, MEK)	Air
			BOD	Water
			TSS	
			COD	
			color	
			chlorophenolics	
			carbon disulfide	
			VOCs (terpenes, alcohols, phenols, methanol, acetone, chloroform, MEK)	

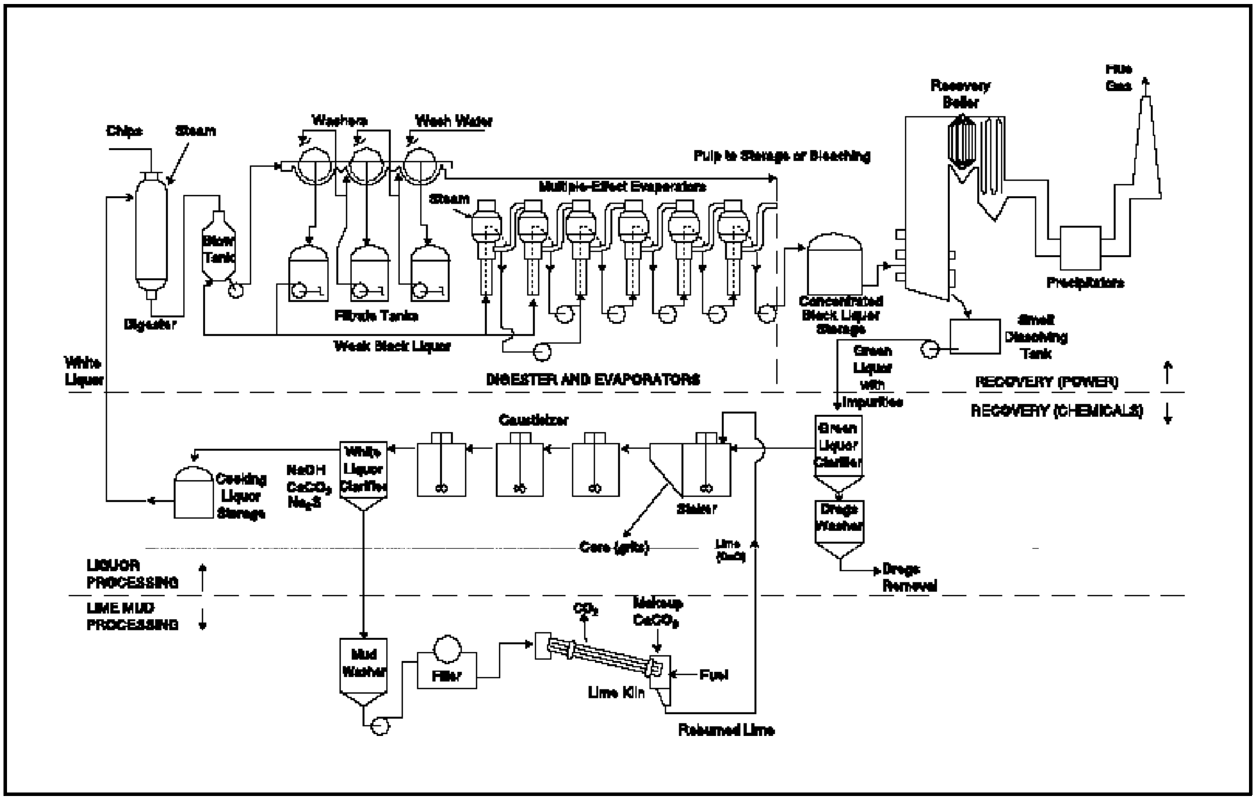
Exhibit 19: Kraft Chemical Pulped-Chlorine Bleached Paper Production

Process Step	**Material Inputs**	**Process Outputs**	**Major Pollutant Outputs***	**Pollutant Media**
Power Boiler	Coal, Wood, Unused furnish	Energy	bottom ash: incombustible fibers	Solid
			SO_2, NO_x, fly ash, coarse particulates	Air
Chemical Recovery System				
Evaporators	Black liquor	Strong black liquor	evaporator noncondensibles (TRS, volatile organic compounds: alcohols, terpenes, phenols)	Air
			evaporator condensates (BOD, suspended solids)	Water
Recovery Furnace	Strong black liquor	Smelt	fine particulates, TRS, sulfur dioxide	Air
		Energy		
Recausticizing	Smelt	Regenerated white liquor	dregs	Solids
		Lime mud	waste mud solids	Water
Calcining (Lime Kiln)	Lime mud	Lime	fine and coarse particulates	Air

* Pollutant outputs may differ significantly based on mill processes and material inputs (e.g., wood chip resin content).
[1] Chlorate only significantly produced in mills with high rates of chlorine dioxide substitution to reduce dioxin and furan production.

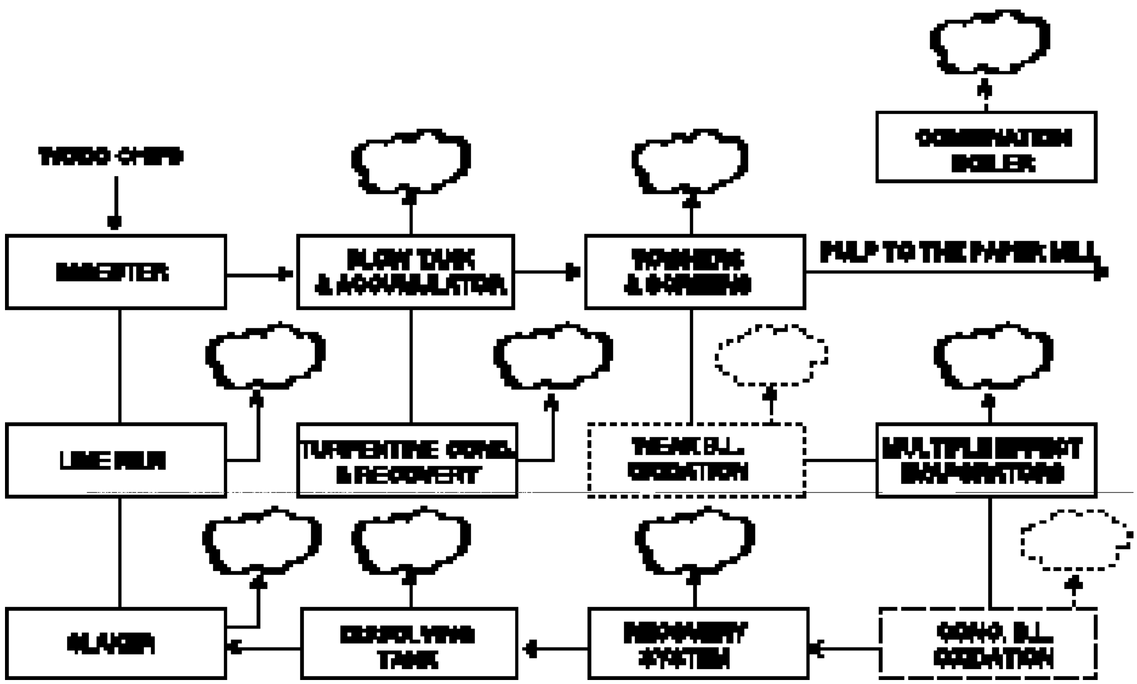
Sources: *Pollution Prevention Technologies for the Bleached Kraft Segment of the U.S. Pulp and Paper Industry* (EPA-600-R-93-110), *Development Document for Proposed Effluent Limitations Guidelines and standards for the Pulp, Paper, and Paperboard Point Source Category (1993)* and air release data from *Pulp, Paper and Paperboard Industry - Background Information for Proposed Air Emission Standards: Manufacturing Processes at Kraft, Sulfite, Soda, and Semi-Chemical Mills (NESHAP; 1993).*

Exhibit 20: Kraft Process Flow Diagram



(Source: Smook, Gary A. *Handbook for Pulp and Paper Technologists*. Second edition. Vancouver: Angus Wilde Publications, 1992.)

Exhibit 21: Air Pollutant Output from Kraft Process



(Source: Smook, Gary A. *Handbook for Pulp and Paper Technologies.* Second Edition. Vancouver: Angus Wilde Publications, 1992.)

III.C. Management of Chemicals in Wastestream

The Pollution Prevention Act of 1990 (PPA) requires facilities to report information about the management of TRI chemicals in waste and efforts made to eliminate or reduce those quantities. These data have been collected annually in Section 8 of the TRI reporting Form R beginning with the 1991 reporting year. The data summarized below cover the years 1992-1995 and are meant to provide a basic understanding of the quantities of waste handled by the industry, the methods typically used to manage this waste, and recent trends in these methods. TRI waste management data can be used to assess trends in source reduction within individual industries and facilities, and for specific TRI chemicals. This information could then be used as a tool in identifying opportunities for pollution prevention compliance assistance activities.

From the yearly data presented below it is apparent that the portion of TRI wastes reported as recycled on-site has increased and the portions treated or managed through energy recovery on-site have decreased between 1992 and 1995 (projected). While the quantities reported for 1992 and 1993 are estimates of quantities already managed, the quantities reported for 1994 and 1995 are projections only. The PPA requires these projections to encourage facilities to consider future waste generation and source reduction of those quantities as well as movement up the waste management hierarchy. Future-year estimates are not commitments that facilities reporting under TRI are required to meet.

Exhibit 22 shows that the pulp and paper industry managed about 2 trillion pounds of production-related waste (total quantity of TRI chemicals in the waste from routine production operations) in 1993 (column B). Column C reveals that of this production-related waste, about 10 percent was either transferred off-site or released to the environment. Column C is calculated by dividing the total TRI transfers and releases by the total quantity of production-related waste. In other words, about 90 percent of the industry's TRI wastes were managed on-site through recycling, energy recovery, or treatment as shown in columns E, F and G, respectively. The majority of waste that is released or transferred off-site can be divided into portions that are recycled off-site, recovered for energy off-site, or treated off-site as shown in columns H, I and J, respectively. The remaining portion of the production related wastes (three percent), shown in column D, is either released to the environment through direct discharges to air, land, water, and underground injection, or it is disposed off-site.

Exhibit 22: Source Reduction and Recycling Activity for Pulp and Paper Industry (SIC 26) as Reported within TRI

A	B	C	D	On-Site			Off-Site		
				E	F	G	H	I	J
Year	Quantity of Production-Related Waste (10^6 lbs.)[a]	% Released and Transferred[b]	% Released and Disposed[c] Off-site	% Recycled	% Energy Recovery	% Treated	% Recycled	% Energy Recovery	% Treated
1992	2,080	10%	10%	5%	10%	74%	.02%	.02%	3%
1993	1,958	9%	9%	5%	10%	74%	.02%	.03%	2%
1994	1,991	--	8%	5%	11%	73%	.02%	.03%	2%
1995	1,949	--	8%	5%	11%	73%	.02%	.02%	2%

[a] Within this industry sector, non-production related waste < 1% of production related wastes for 1993.
[b] Total TRI transfers and releases as reported in Section 5 and 6 of Form R as a percentage of production related wastes.
[c] Percentage of production related waste released to the environment and transferred off-site for disposal.